Yield Of Crested Wheatgrass Under Four Densities Of Big Sagebrush In Southern Idaho

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by

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SUMMARY

This study shows how three methods of sagebrush control and four densities of sagebrush affected: (1) yields of crested wheatgrass growing under sagebrush, (2) amount of rain and snow reaching the soil, and (3) soil moisture content.

The study was conducted at two areas in southern Idaho: (1) Holbrook, a favorable site for plant growth, having 16 inches of annual precipitation; and (2) Twin Falls, less productive, but still a good site, having 9 inches of annual precipitation.

Both sites were cleared of big sagebrush in 1950 and 1954 and seeded to crested wheatgrass. Sagebrush rapidly reinvaded the seeded ranges to a density of 20 plants per 100 square feet. In 1965, sagebrush was reduced to 10, 5, and 0 plants per 100 square feet (50-, 75-, and 100-percent kills) by grubbing, burning, and spraying with 2,4-D. The three methods did not differ in the amount of grass produced following brush control.

As the sagebrush was decreased, the yield of wheatgrass increased. From 1967 to 1970, crested wheatgrass in a full stand of sagebrush at Holbrook averaged 490 pounds per acre. After the sagebrush was killed, grass averaged 1,522 pounds per acre—an increase of 1,032 pounds. At Twin Falls, the grass under sagebrush averaged 442 pounds per acre. After the sagebrush was controlled, grass averaged 1,080 pounds per acre—an increase of 638 pounds.

Where wildlife or domestic livestock do not need sagebrush, all the brush should be killed. Any remaining sagebrush suppresses grass and also produces seed for reinvasion. The last remaining sagebrush reduces grass growth the most. For example, killing the last 25 percent of the sagebrush resulted in 135 percent more grass at Holbrook and 98 percent more at Twin Falls than when the first 75 percent of the brush was killed on these areas.

In 1970, sagebrush on the untreated plots weighed 802 pounds per acre at Holbrook and 304 pounds per acre at Twin Falls. The untreated sagebrush plant canopy covered 33.7 percent of the ground at Holbrook and 11.4 percent at Twin Falls. When 75 percent of the sagebrush was killed in 1965, the remaining plants increased in size and by 1970 were double in canopy cover and weight when compared to sagebrush plants on the untreated plots.

Soil moisture was higher under the brush-free grass than under the sagebrush. Sagebrush intercepted 30 percent of the rain and 37 percent of the snow as compared to the brush-free plots. Soil moisture at the deeper depths under sagebrush was seldom recharged by winter precipitation.

At Holbrook, sagebrush plant roots reached down to 72 inches and spread laterally to 60 inches. Under sagebrush, the crested wheatgrass roots reached to 42 inches and spread to 20 inches. On brush-free areas, crested wheatgrass roots reached depths of 60 inches with a lateral spread of 36 inches. Sagebrush roots growing with grass amounted to 23,788 pounds per acre. Crested wheatgrass roots totaled 10,955 pounds per acre when growing with big sagebrush and 15,132 pounds per acre on brush-free areas.

INTRODUCTION

Each year in southern Idaho, and in surrounding States, thousands of dollars are spent to control sagebrush [1] that reinvades and reduces yields of seeded grass stands, mainly crested wheatgrass.[2] To make sagebrush control more effective, we need to determine how different methods of sagebrush control affect sagebrush and the associated grass understory, and how partial and complete control influence sagebrush stands and the amount of grass produced. Therefore, this study was designed to determine: (1) How three methods of sagebrush control and four densities of big sagebrush affect yields of the crested wheatgrass understory, and (2) how four densities of big sagebrush affect: (a) rain and snow reaching the soil, and (b) soil moisture content.

In southern Idaho, sagebrush will reinvade areas from which it has been removed by fire, herbicides, or cultivation (Piemeisel, *1932*; [3]

[1] Common and scientific names of species mentioned are listed on p. 38.

[2] Seeded stands of crested wheatgrass often contain considerable fairway wheatgrass. Except where specifically mentioned, both species will be referred to as crested wheatgrass.

[3] The author's name followed by an italicized year refers to Literature Cited, p. 36.

Hull and Klomp, *1966*; and Tisdale et al., *1969*). Sagebrush also invades native and seeded ranges in surrounding States (Hedrick et al., *1964*; Johnson, *1969*; and Robertson et al., *1966*).

Investigators in Idaho and adjacent States have found that big sagebrush reduces the yield of native and of seeded grasses (Blaisdell, *1949*; Hull and Holmgren, *1964*; Hyder and Sneva, *1956*; Pechanec et al., *1965*; Plummer et al., *1955*; Robertson and Pearse, *1945*; Tisdale et al., *1969*). In southern Idaho, a stand of big sagebrush having 20 plants per 100 square feet and a native grass understory of 50 pounds per acre was burned and seeded to crested wheatgrass. Two years after sagebrush control, the native grass increased to 335 pounds, and the seeded grass yielded 1,786 pounds for a total of 2,120 pounds per acre (Hull and Anderson, *1947*). In Nevada, seeded grass in the open produced three to four times more herbage than grass which was competing with sagebrush (Robertson, *1947*).

In central Utah, Cook (*1958*, *1966*) stated that for every 1 percent increase in sagebrush cover, there is a decrease of 8.6 pounds per acre of seeded grass and that a heavy stand of brush may reduce the potential grass yield by 70 percent. Also in central Utah, Frischknecht (*1963*) and Frischknecht and Harris (*1968*) reported that big sagebrush reduced stands of crested wheatgrass more than did rubber rabbitbrush. They concluded that sagebrush and crested wheatgrass compete intensely because their roots are in the same soil zone, and they grow actively at the same season. Most of the sagebrush roots were lateral and grew in the top 14 inches of the soil; some roots extended out 72 inches from the stem.

At 9,500 feet elevation in Wyoming, roots of three sagebrush plants ranged from 48 to 72 inches in depth and extended 36 to 60 inches laterally. Sixty-two percent of the roots were in the upper 23.6 inches of soil (Tabler, *1964*).

A sagebrush cover reduces soil moisture. A major loss of soil water occurs through sagebrush leaves which remain on the plant and transpire all year. Because of reflected heat, snow adjacent to sagebrush melts as much as 2 weeks earlier (Robertson and Pearse, *1945*; Robertson, *1947*).

Snow melting by reflected heat from sagebrush affects snow retention and soil moisture. Two areas of big sagebrush in Wyoming were treated with 2,4-D and checked for snow retention. In the Red Desert, there was no difference in snow retention, but the treated area had more soil moisture than did the live brush area. In the Big Horn Mountains, the treated area retained snow later in the spring and had more soil moisture than did live brush areas (Sonder and Alley, *1961*).

EXPERIMENTAL AREAS

This study was made at two areas of sagebrush-grass type in southern Idaho—Holbrook and Twin Falls. Each had a dense stand of big sagebrush [4] with an excellent understory of crested wheatgrass. Both sites are representative of sagebrush lands that were cleared of big sagebrush, seeded to crested wheatgrass, and reinvaded by sagebrush (fig. 1).

Holbrook

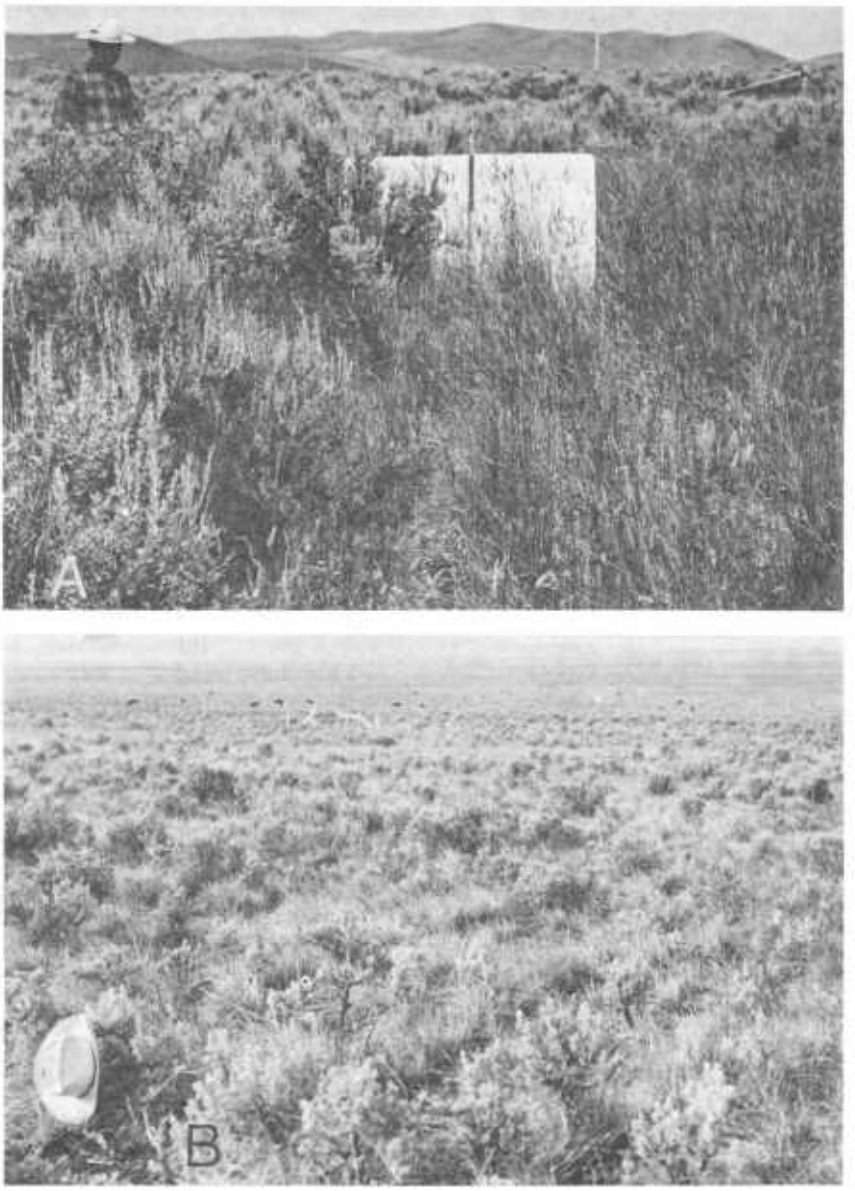
The Holbrook experimental site is 4 miles east and 4 miles north of Holbrook, Idaho, on the Curlew Grassland of the Caribou National Forest. It receives 16 inches annual precipitation and has relatively favorable growing conditions (table 1). The area has a gently rolling topography with 5 percent southwest slope. The site is 5,200 feet in elevation and is on the highest shoreline level of prehistoric Lake Bonneville.

The soil is a deep Parleys silt loam. It is friable with no rock to 72 inches. A light-colored carbonate layer at 16 to 36 inches does not appear to stop root or moisture penetration. The pH is 7.6. The upper 12 inches is 32 percent sand, 53 percent silt, and 15 percent clay; and the bulk density is 1.25. The soil holds 12 percent water or 1.8 inches per foot at 15 bars tension or wilting and 26 percent at one-third bar or field capacity. These characteristics show no appreciable change to a depth of 48 inches. The upper 6 inches of soil contains 2 percent organic matter and 0.5 percent at 48 inches. There is 0.13 percent nitrogen in the upper 6 inches and 0.04 percent at 48 inches.

The Holbrook area was cleared of big sagebrush in 1910 and grew dryland wheat until 1937. After farming was abandoned, sagebrush reinvaded. In the fall of 1950, the sagebrush was burned and 1,440 acres drilled to a mixture of crested wheatgrass, 5 pounds per acre; bulbous bluegrass, 1 pound per acre; and Ladak alfalfa, 1 pound per acre. Grazing commenced in 1952 and averaged 4.8 acres per cow month through 1964.

Basin big sagebrush commenced reinvasion in 1951, the same year as the grass seedlings emerged. This was the year of greatest sagebrush establishment. By 1965, the sagebrush plants were tall and dense. Mature sagebrush plants averaged 42 inches in height, and

[4] The sagebrush at Holbrook is basin big sagebrush. The sagebrush at Twin Falls is Wyoming big sagebrush. In this study, both will be called big sagebrush.



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FIOURE 1.—Experimental areas. *A*, Plant growth at Holbrook is excellent. The untreated plot on the left has sagebrush 45 inches tall, which suppressed crested wheatgrass so that in 1970 the plot yielded only 551 pounds per acre, as compared to 1,827 pounds of grass on the brush-controlled plot on the right. *B*, At Twin Falls, the sagebrush and grass are shorter than at Holbrook. The untreated brush plots are in the left foreground and the background. The 50-percent grubbed plot is in the right foreground.

some were over 60 inches. The average crown diameter of mature plants was about 26 inches but sometimes exceeded 40 inches.

In 1965, there were 20.2 sagebrush plants per 100 sq. ft. comprised of 16.2 mature plants (11 to 15 years old), 2.4 young plants (4 to 10 years old), and 1.6 seedlings (1 to 3 years old). On the 0.73 acres of treated plots, 12 plants were threetip sagebrush and five plants, Douglas rabbitbrush. The threetip sagebrush was counted as big sagebrush, and the rabbitbrush was disregarded.

Crested wheatgrass formed a good understory stand with approximately 1.5 plants per sq. ft. Some of the plots had a few plants of fairway wheatgrass, alfalfa, and milkvetch and many plants of bulbous bluegrass. This latter species grows early in the spring,

TABLE 1.—*Average annual precipitation and precipitation during the years of the study at Holbrook and Twin Falls* [1]

Months	Inches of precipitation						
	Average	1964-65	1966-67	1965-66	1969-70	1968-69	1967-68
October	1.1		0.1	0.1	0.7	0.9	1.1
	(.7)			(.1)	(.9)	(.4)	(.9)
November	1.3		3.7	1.4	.1	1.9	.9
	(.9)			(0)	(0)	(2.1)	(.6)
December	1.6		1.5	1.8	1.5	2.1	1.6
	(1.0)					(1.8)	(1.3)
January	1.8		1.7	1.8	.6	4.8	4.0
	(1.1)					(.4)	(3.4)
February	1.4		1.7	1.1	2.3	2.3	.3
	(.7)					(.7)	(.3)
March	1.4		1.0	1.7	1.3	.3	1.2
	(.9)			(1.2)	(.7)	(.1)	(.2)
April	1.5	3.7	.5	2.9	1.1	.5	.8
	(1.0)	(1.6)	(.3)	(1.9)	(.2)	(.5)	(1.2)
May	1.9	1.4	1.8	1.6	1.5	.2	1.8
	(1.1)	(1.1)	(1.0)	(.9)	(.9)	(.1)	(2.1)
June	1.4	2.7	.6	2.9	1.9	2.4	1.8
	(.9)	(.6)	(.2)	(1.9)	(1.3)	(2.1)	(1.6)
July	.8	1.1	.1	.9	1.3	.2	1.6
	(.3)		(.2)	(.3)	(0)	(.5)	(1.1)
August	.8	1.2	.6	0	4.3	.5	.1
	(.3)		(0)	(0)	(3.0)	(0)	(1.0)
September	1.0	1.3	.4	.2	.2	.2	1.0
	(.4)		(.4)		(.2)	(.4)	(.1)
Total annual	16.0		13.7	16.4	16.8	16.3	16.2
	(9.3)					(9.1)	(13.8)
Percent normal [2]	100	127	86	102	105	102	101
	(100)	(110)	(52)	(103)	(111)	(98)	(148)

[1] Twin Falls values are in parentheses.

[2] Percentage of normal precipitation for the period measured.

and, though it provides some early grazing, it contributed little to the harvested grass yields. The average yield of grass before sagebrush treatments in 1965 was 650 pounds per acre, but sagebrush made an estimated 60 percent of the grass unavailable to grazing animals (fig. 2). Because of sagebrush competition, many of the crested wheatgrass plants were small and low in vigor. Where sagebrush was not present, the grass plants were vigorous with bunches about 6 inches in diameter. Maximum height of seedstalks during the past 6 years has ranged from 24 to 36 inches.

Twin Falls

The Twin Falls experimental site is 8 miles west and 10 miles south of Twin Falls, Idaho, on the Berger tract of the Burley district, Bureau of Land Management. It receives an average of 9.3 inches of precipitation annually and is not as productive as Holbrook (table 1). The general area slopes 4 percent to the southwest. The elevation is about 4,600 feet.

The soil is a stony Minveno silt loam but is friable and productive. The entire area is basaltic and has many surface rocks up to 12 inches in diameter. The rocks become more abundant with depth. Rocks comprise an estimated 25 percent of the volume of the top 18 inches of the soil profile. Rocks larger than 2 millimeters are excluded in soil analyses. A light-colored carbonate layer at 13 to

PN-3565

FIGURE 2.—Sagebrush at Holbrook was burned and the area was drilled to crested wheatgrass in the fall of 1950. This photograph, taken in 1965, shows the type of brush and a general view of the area as seen from 150 feet northeast of the experimental plots.

18 inches does not appear to hinder root penetration. The pH is 7.7. The soil averages 33 percent sand, 54 percent silt, and 13 percent clay; and the bulk density is 1.23. The soil holds 13 percent water or 1.9 inches per foot at 15 bars tension or wilting and 26 percent at one-third bar or field capacity. The upper 6 inches of soil contain 1.9 percent organic matter and 1.4 percent at 18 inches. There is 0.2 percent nitrogen in the upper 6 inches and 0.1 percent at 18 inches.

The area originally grew Wyoming big sagebrush and an understory of grasses and other herbaceous plants. Excessive grazing reduced the carrying capacity to where 28 acres were required per cow month. Piemeisel (*1945*) found that native perennials did not increase in this area from 1931 to 1944, even when protected from livestock grazing.

In July 1954, the area was plowed with a wheatland-type plow and drilled with a mixture of 5 pounds per acre crested wheatgrass and 0.5 pound per acre of Ladak alfalfa. The seeded range was first grazed in November 1956. Currently, this range is rated at 2.5 acres per cow month. Adjacent seeded range with less sagebrush is rated at 1.5 acres per cow month.

Some brush was not killed by plowing, but most sagebrush present in 1965 was the result of reinvasion in 1955. The mature sagebrush plants averaged 18 inches in height with some reaching 30 inches. There were 21 sagebrush plants per 100 sq. ft. with 18 mature (8 to 15+ years old), three young (4 to 7 years), and a trace of seedlings. By 1965, the sagebrush made an estimated 30 percent of the grass unavailable to grazing animals.

There was a good stand of seeded grass, about 75 percent fairway and 25 percent crested wheatgrass. The average yield before sagebrush treatment in 1965 was 470 pounds per acre. Crested wheatgrass averaged 1.3 plants per sq. ft. The plants averaged 4 inches in diameter and were well established and vigorous. The seedstalks ranged from 15 to 22 inches in height. The numbers of plants per 100 sq. ft. of other plants on the study area were as follows: Sandberg bluegrass, 0.2; squirreltail, 0.2; Thurber needlegrass, 0.1; streambank wheatgrass, trace; and cheatgrass, trace.

EXPERIMENTAL METHODS

Both areas were fenced to exclude livestock. Because of heavy rabbit infestation on both areas, rabbit-proof netting was added to the fences in 1969.

The study was designed for 4 years (1965–68). Because of an ex-

ceptionally dry year and low yields in 1966, relatively low yields in 1968, and rabbit damage in 1969, it was extended to 6 years.

Brush Treatments

In 1964, we laid out 30 40- by 40-foot plots (0.037 acre each) on each area and subdivided each plot into 16 10- by 10-foot subdivisions. On each plot and its subdivisions, we counted sagebrush by age classes and evaluated the grass stands. The 10 plots having the least uniform stands of sagebrush and grass were discarded. The following 10-brush control treatments were then randomly assigned 10 plots in each of two replicate blocks on each area:

1. No sagebrush treatment, 20 sagebrush plants per 100 sq. ft.
2. Grub 50 percent of the sagebrush plants.
3. Grub 75 percent of the sagebrush plants.
4. Grub all sagebrush plants.
5. Burn and kill 50 percent of the sagebrush plants.
6. Burn and kill 75 percent of the sagebrush plants.
7. Burn and kill all sagebrush plants.
8. Spray with 2,4-D and kill 50 percent of the sagebrush plants.
9. Spray with 2,4-D and kill 75 percent of the sagebrush plants.
10. Spray with 2,4-D and kill all sagebrush plants.

To get equal distribution of sagebrush by age classes within each 10-foot subdivision, we tied plastic ribbons on all plants to be left alive. Grubbed plants were cut near the ground level with an axe or with a brush-cutting powersaw in July 1965. Plants stayed where they fell, and at Holbrook they formed a deep litter (fig. 3).

Burning was done in October 1965 with a weed burner. Wood and metal shields were used to confine the fire.

Plants to be killed with 2,4-D (2,4-dichlorophenoxyacetic acid) were sprayed in July 1965 with as near a concentration as possible of 2 pounds per acre of low-volatile ester. Red food coloring in the spray helped prevent double spraying. In 1966, we checked each plot and subdivision for the exact amount of brush. Additional kills of one or two plants were made on some of the spray plots.

In 1964, we grubbed and removed all brush from four discard plots on each area to have grass plots to check the 1965 complete kill treatments. Except for being 1 year early, appearance and yields of these plots were similar to the 100-percent control treatments in 1965. In 1968, we grubbed 90 percent of the sagebrush on two discard plots on each area to leave two plants per 100 sq. ft. Game managers recommend this as a desirable amount of sagebrush

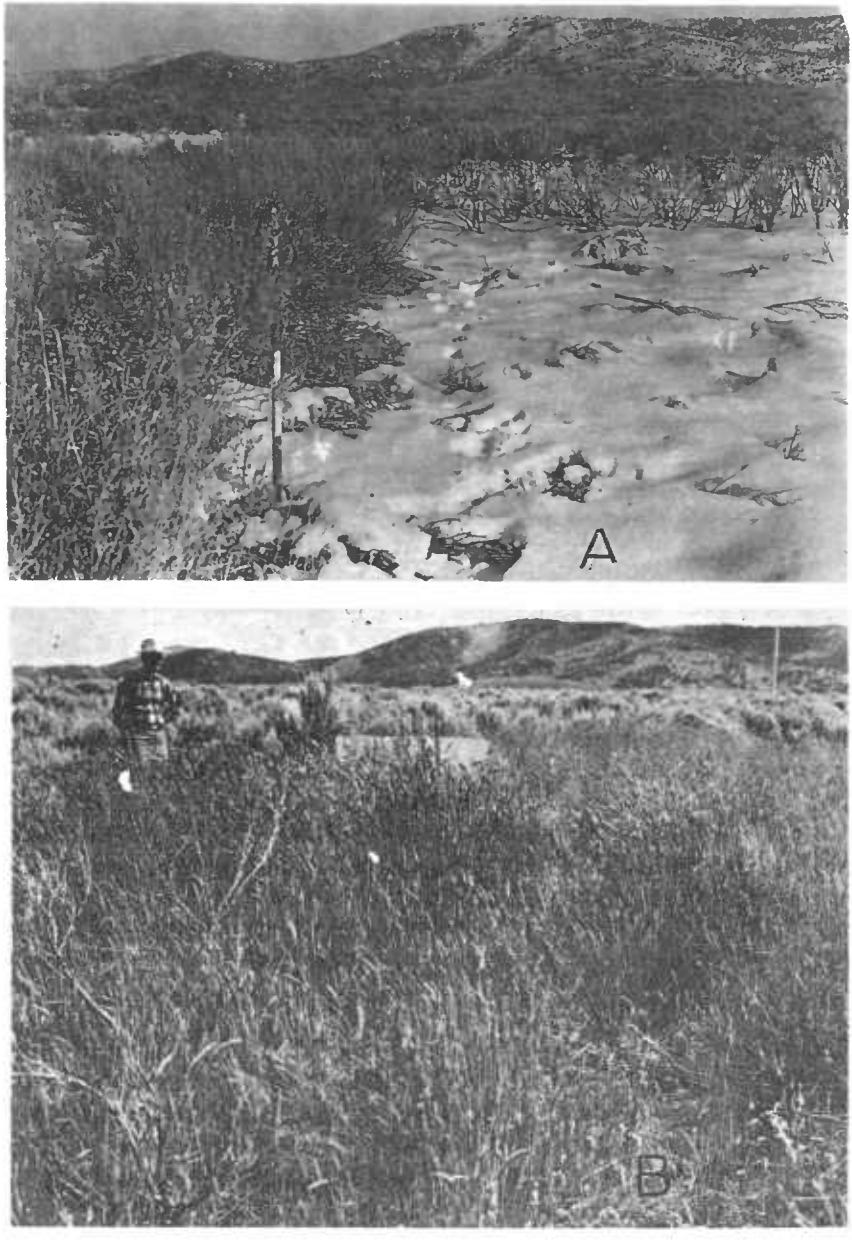

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FIGURE 3.—Result of brush treatment at Holbrook is shown by 2 photographs taken at the same location. *A*, Photograph taken in December 1965 shows sprayed plants standing but with dead leaves. *B*, Photograph taken in 1970 shows dead standing brush on sprayed plot in left foreground and crested wheatgrass up to 40 inches tall on both plots. Grass yields were increased 300 percent through brush control.

for game birds and animals. A summary of percent sagebrush kill and plant densities for all control treatments follows:

Kill percent	*Plants per 100 sq. ft.*	*Plants per acre*
0	20	8,712
50	10	4,356
75	5	2,178
90	2	871
100	0	0

Grass Yields

The center 24-foot square of each plot was divided into 16 1.5- by 24-foot strips on which we obtained yields of grass. Four strips on each plot were clipped each year for grass yields. In early October, before each sampling, the dry grass on these strips was cut and left on the plot. Clippings were taken in late June. Grass was cut as near the ground as possible and averaged about 1 inch stubble height (fig. 4). Samples for the fifth and sixth years were taken on plots which had been clipped 4 years previously.

Sagebrush Canopy Cover and Yields

In 1970, we obtained yields and canopy cover on the three densities of sagebrush (5, 10, 20 plants per 100 sq. ft. or 75, 50, 0 percent kill) at each location. Yields were obtained by clipping and estimating the current twig and leaf growth on 32 9.6-sq. ft. circular plots in each brush density at each location. Crown or canopy cover was that percentage of a 40-foot transect line occupied by the crown of sagebrush plants. There were 20 transect lines within each of the three brush densities at each location.

Soil Samples

We took monthly soil moisture samples with a 2.75-inch diameter bucket auger from April 1 to November 1 on the 100-percent grubbed plots, the three densities of brush on the burn treatments, and on the untreated sagebrush plots. Samples were taken at 0 to 6, 6 to 12, 12 to 24, 24 to 36, and 36 to 48 inches at Holbrook. Because of rocks at Twin Falls, it was not feasible to go below 24 inches. During 1969 and 1970, soil moisture samples were taken throughout the year at Holbrook.

At all dates and depths on the brush plots during 1966, we took soil samples next to the sagebrush stem, under the brush canopy, and in the open between sagebrush plants which were 6 to 10 feet

PN-3568/PN-3569

FIGURE 4.—Grass yield strips at Twin Falls. *A*, Sagebrush on this plot was killed by grubbing. The crested wheatgrass shown produced 1,258 pounds per acre in 1970. *B*, Check plot with 20 sagebrush plants per 100 sq. ft. produced 667 pounds of grass per acre in 1970.

apart. This was discontinued because there was no significant difference in soil moisture among these three locations.

During 1968 and 1969 at Holbrook and 1969 at Twin Falls, we sampled all soil depths for bulk density. These figures were used to convert percent moisture to inches of water.

Precipitation

Monthly precipitation was measured with an 8-inch modified Bozeman storage gage (Gomm, *1961*) on each area (table 1). We measured snow depth and water content of the snow cover at Holbrook monthly during the winter by taking 40 random samples on each of the four sagebrush intensities. Ten snow cores were taken to calculate percent water in the snow. Snow cover at Twin Falls was too light to measure.

Rainfall and Snow Interception

We determined the amount of monthly April 1 to October 30 rainfall reaching the soil by catching the rain in small gages during 1966 to 1970. The top of the gage was a 4-inch diameter funnel 4 inches above the soil surface. Underground plastic bottles stored the rain falling in the funnels. The small end of the funnel was constricted and taped to prevent evaporation (fig. 5). Gages were placed at mechanical spacings and were then classified as: (1) in the open, (2) under medium brush cover, or (3) under heavy sagebrush cover. Rain gage placements were adjusted at Twin Falls to have the same percentage in each brush cover class as at Holbrook. Each location had 65 gages with the number under each sagebrush cover class as follows:

		Sagebrush canopy	
Kill of sagebrush plants	*None*	*Medium*	*Heavy*
No treatment	6	8	6
50 percent burned	4	4	2
75 percent burned	6	3	1
100 percent burned or grubbed	10	—	—
By 8-inch gage	5	—	—

To determine the interceptions and water holding capacity of sagebrush plants, we cut 30 mature plants and applied water on 20 of them as follows: Three plants were cut at the same time and weighed. One was sprayed with a rainlike spray until leaves started to drip water, one was immersed in a barrel of water, and the third was not treated. After the water treatments, plants were hung upright and weighed at the following intervals: 10, 30, and 60 minutes; 2, 3, 4, 5, and 24 hours; and 2, 7, 14, 21, 28, and 35 days during July and early August 1971.

PN-3570

FIGURE 5.—Four-inch funnels with plastic underground bottles (foreground) were used as gages to catch rain. Sagebrush like this heavy stand at Holbrook intercepted over 50 percent of the rain and snow.

Roots

In 1970, three soil cores were taken at Holbrook to determine the amount of sagebrush and grass roots at various depths. In 1971, two trenches, 30 feet long and 6 feet deep, were dug to determine root distribution of sagebrush and crested wheatgrass plants. Within the trenches, root systems were exposed by using a fine spray of water and an ice pick to remove the soil. Root volume samples were taken in each trench.

Grazing

Each summer following herbage yield determinations, the experimental sites were grazed by cattle or horses at Holbrook and by cattle at Twin Falls.

RESULTS AND DISCUSSION

Brush Treatments and Grass Yields

To briefly summarize the results, the less sagebrush the more grass (table 2). Any intensity of sagebrush control, regardless of

method, increased the amount of grass. The three methods of sagebrush control did not differ significantly in the amount of grass produced following treatment. Therefore, all methods are averaged.

At both locations, the year after brush control was a poor year for grass growth. In the next year, 1967, growing conditions were above normal. During these 2 years, the grass that had been suppressed by sagebrush recovered rapidly and yielded near optimum. Thus

TABLE 2.—*Pounds of air-dry grass per acre under three methods and four intensities of sagebrush control at Holbrook and Twin Falls, 1965–70*

Control method	Percent kill of sagebrush	Pounds per year of yield[1]					
		1965	1966	1967	1968	1969	1970
Holbrook:							
No treatment		627a	397a	555a	503a	400a	502a
Burn	50	606	390	793	758	549	662
Spray	50	675	403	866	722	457	668
Grub	50	634	391	892	636	527	673
Average		638a	395a	850b	705b	511b	668b
Burn	75	651	502	1,187	1,164	804	1,132
Spray	75	687	531	1,043	887	774	910
Grub	75	678	481	896	811	694	842
Average		672a	505b	1,042c	954c	757c	961c
Burn	100	682	538	1,628	1,602	1,127	1,797
Spray	100	570	545	1,553	1,324	1,209	1,937
Grub	100	675	660	1,599	1,479	1,119	1,888
Average		642a	581b	1,593d	1,468d	1,152d	1,874d
Twin Falls:							
No treatment		498a	210a	415a	250a	452a	652a
Burn	50	443	159	562	327	554	857
Spray	50	429	201	481	312	552	857
Grub	50	467	203	561	307	546	766
Average		446a	188a	535b	315b	551b	827b
Burn	75	458	181	577	407	591	984
Spray	75	510	212	637	373	582	1,017
Grub	75	528	210	554	387	617	929
Average		499a	201a	589b	389c	597b	977c
Burn	100	434	197	849	560	725	1,326
Spray	100	473	250	714	522	873	1,227
Grub	100	466	245	767	512	691	1,196
Average		458a	231a	777c	531d	763c	1,250d

[1] Within each year, any 2 means followed by the same letter are not significantly different at the 5-percent level ($sx = 19.3$).

with near normal precipitation approximately 2 years of moderate use should bring a stand of grass to full productivity after brush control in these areas (figs. 6, 7, 8).

Complete control of sagebrush results in the greatest increase of grass yields. Averaging the last 4 years (1967–70), after stands reached full productivity, grass under a full stand of sagebrush at Holbrook produced 490 pounds per acre, air dry. Killing half the brush increased yields by 193 pounds, whereas killing the remaining half increased yields an additional 839 pounds. This is a total increase of 211 percent over the check. At Twin Falls, the 4-year average of grass under sagebrush was 442 pounds per acre. Killing 50 and 100 percent of the brush resulted in increases of 115 and 388 pounds per acre, respectively. This is a total increase of 88 percent over the check (fig. 9).

Where domestic livestock or wildlife do not need sagebrush for feed or cover, or where it is not important for erosion control, all the brush should be killed. Any remaining brush is a seed source for reinvasion. In addition, the last remaining sagebrush plants suppress grass proportionately more per plant than does a full stand. Killing 75 percent of the sagebrush at Holbrook increased grass yields by 439 pounds per acre. Killing the remaining 25 percent increased yields an additional 593 pounds per acre. Also at Twin Falls, killing 75 percent of the brush increased grass yields by 196 pounds per acre with an additional increase of 192 pounds per acre for the remaining 25 percent (fig. 10).

The plots with the 90 percent reduction or two sagebrush plants per 100 sq. ft. were treated in 1968. Grass yields increased on these plots as compared to the check plots. In 1970, these plots produced 917 pounds per acre air-dry at Holbrook and 991 pounds per acre at Twin Falls (fig. 11).

Sagebrush Canopy Cover and Yields

As we made sagebrush control treatments in 1965, we killed plants so that plants remaining on the 16 10-foot-square subdivisions would be similar in size and age class among subdivisions and also among plots. Brush yields and crown cover were then in rough proportion to the number of sagebrush plants per plot. As the study neared completion, it was apparent that the remaining individual sagebrush plants on thinned stands were increasing in size. This was especially noticeable at Holbrook.

The untreated areas had a sagebrush canopy cover of 33.7 percent at Holbrook and 11.4 percent at Twin Falls. When 75 percent of the sagebrush plants were killed, the canopy cover remaining was

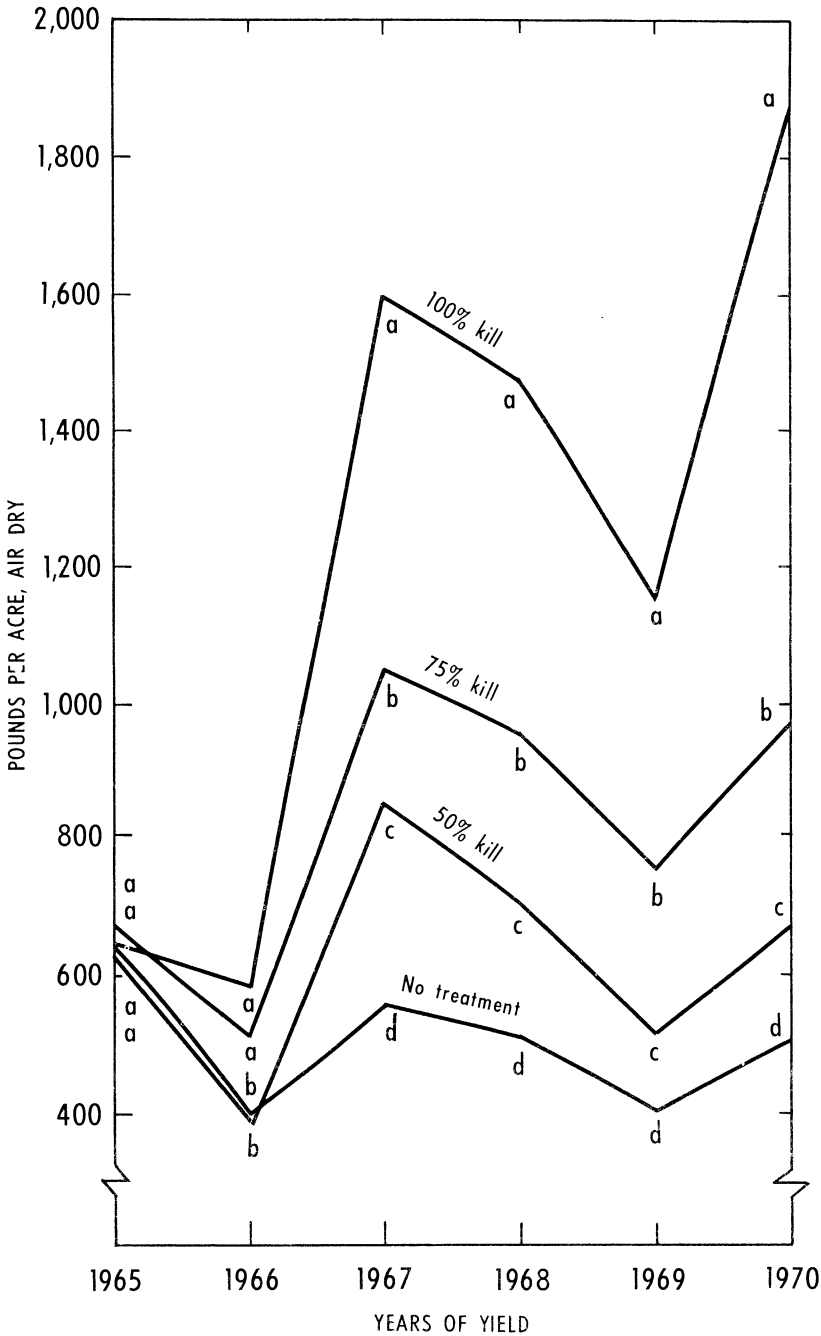

FIGURE 6.—Yields of crested wheatgrass under 4 degrees of sagebrush control at Holbrook, 1965–70. Within each year, any 2 points with the same letter are not significantly different at the 5-percent level.

22.4 percent at Holbrook and 5.8 percent at Twin Falls. Because the individual plants had increased in size, this cover was double the expected amount (table 3).

As plants increased in crown diameter, there were more and larger plants along the transect lines. The number of sagebrush plants that fell along the transects should have been in a 20, 10, and 5 ratio.

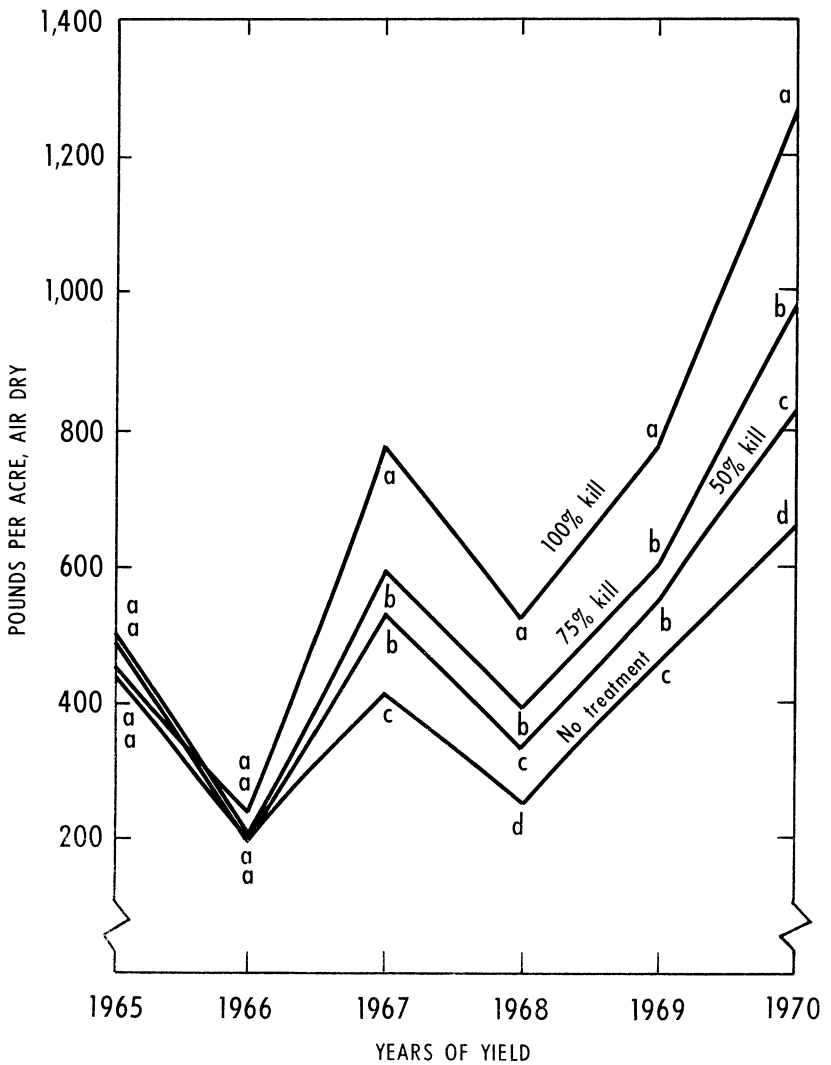

FIGURE 7.—Yields of crested wheatgrass under 4 degrees of sagebrush control at Twin Falls, 1965–70. Within each year, any 2 points with the same letter are not significantly different at the 5-percent level.

The 1970 ratio was 20, 14, and 8 at Holbrook and 20, 12, and 6 at Twin Falls.

The 1970 yields of individual sagebrush plants were higher from plots with fewer plants than from plots with many plants. The smallest number of sagebrush plants at Holbrook, 5.2 per 100 sq. ft., produced 506 pounds per acre of sagebrush. Four times this many sagebrush plants did not even double the production. At Twin Falls, it took five times more plants to double the production (table 4).

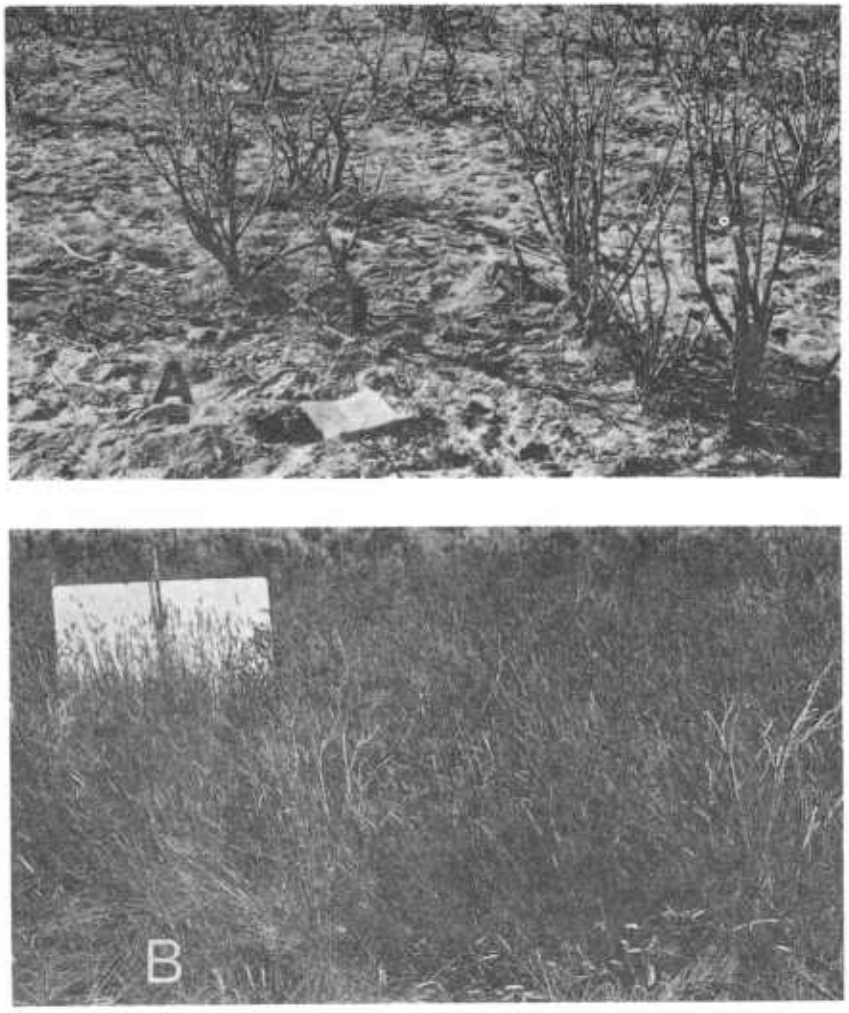

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FIGURE 8.—*A*, The brush on this plot at Holbrook was burned in 1965. When this photograph was taken in 1966, the grass had been heavily grazed. *B*, The same plot in 1970 had a heavy stand of grass that produced 1,797 pounds per acre.

The Holbrook yield of 802 pounds per acre of sagebrush was higher than other yields for Idaho (Blaisdell, *1953*; Passey and Hugie, *1962* and *1963*). A higher yield is expected because these study areas were selected for a heavy stand of sagebrush with a suppressed understory of crested wheatgrass.

The total sagebrush plant material yield is high. An indication of total yields is obtained from the 30 mature plants cut for water interception studies at Holbrook. Plants averaged 4.10 pounds each

TABLE 3.—*Actual and expected lineal feet of sagebrush canopy and crown diameter at point of interception per 100-foot transect under 3 densities of sagebrush at Holbrook and Twin Falls in 1970*

Sagebrush control (percent)	Lineal feet of canopy		Average diameter
	Actual	Expected [1]	
	Feet	*Feet*	*Inches*
Holbrook:			
None	32.7	32.7	12.3
50	28.7	16.4	15.4
75	22.4	8.2	20.6
Twin Falls:			
None	11.4	11.4	7.2
50	6.8	5.7	8.5
75	5.8	2.9	12.7

[1] Calculated from the total number of sagebrush plants.

TABLE 4.—*Actual and expected pounds per acre of air-dry current growth and plants per 100 sq. ft. of sagebrush under 3 densities of sagebrush at Holbrook and Twin Falls in 1970*

Sagebrush plants per 100 sq. ft.	Sagebrush		Sagebrush plants per 100 sq. ft.
	Actual	Expected [1]	
	Pounds per acre	*Pounds per acre*	*Number*
Holbrook:			
20	802	802	20.3
10	603	401	9.9
5	506	200	5.2
Twin Falls:			
20	304	304	19.8
10	210	152	9.4
5	143	76	4.2

[1] Calculated from the total number of sagebrush plants.

immediately after cutting. They weighed 2.62 pounds each after being air dried for 35 days until they stopped losing weight. At Holbrook, the number of mature sagebrush plants averaged 7,056 per acre; thus, the total yield, air dry, was 18,487 pounds per acre. The growing portion of this plant material uses water, and the total makes 60 percent of the grass unavailable to grazing animals.

Soil Moisture

Analysis of the extensive soil moisture samples showed that the moisture trend was similar for each year. Therefore, at each soil depth and month we averaged the amount of water for the years of the study. Soil moisture in the brush plots with five and 10 sagebrush plants per 100 sq. ft. was intermediate between the plots with 20 sagebrush plants per 100 sq. ft. and the grass plots with no sagebrush, and it is not shown on tables 5 and 6.

Holbrook

The soil at Holbrook holds approximately 1.8 inches of water per foot of soil at 15 bars tension or approximate wilting and 3.9 inches at one-third bar tension or field capacity. Throughout the entire study, there was more soil moisture under the grass than under the sagebrush and grass. Undoubtedly, the two main factors were less precipitation reaching the soil because of rainfall interception by

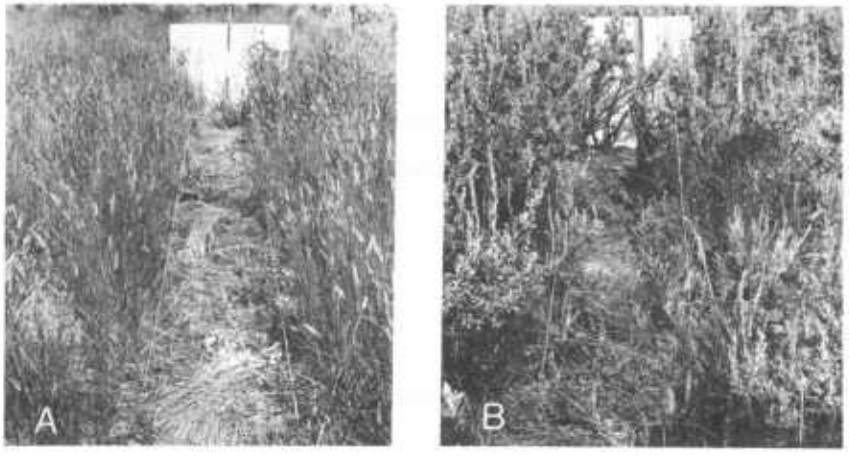

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FIGURE 9.—Strips clipped for grass yields at Holbrook. *A*, Where brush was killed by burning, this plot produced 1,827 pounds per acre of crested wheatgrass in 1970. *B*, Where brush was not controlled, crested wheatgrass yielded 551 pounds per acre.

the sagebrush and more water used by grass and sagebrush than by grass alone. Sagebrush, being nondeciduous, uses water throughout the year but grass is dormant several months.

We took soil moisture samples every month in 1969 and 1970. An averaging of all five sampling depths showed from 1.6 to 2 inches more moisture under the grass than under the sagebrush and the grass every month of the year (fig. 12). Soil moisture under the grass never fell below wilting. Soil moisture under the sagebrush and grass was below wilting from July to December.

Considering the five depths individually, the greatest difference in soil moisture under the grass and under the sagebrush and grass was at the deeper depths. At 12 to 24 and 36 to 48 inches, soil moisture under the grass was alway above the wilting point. Soil moisture under the sagebrush and grass was above the wilting point only in the spring. There was little difference in the amount of

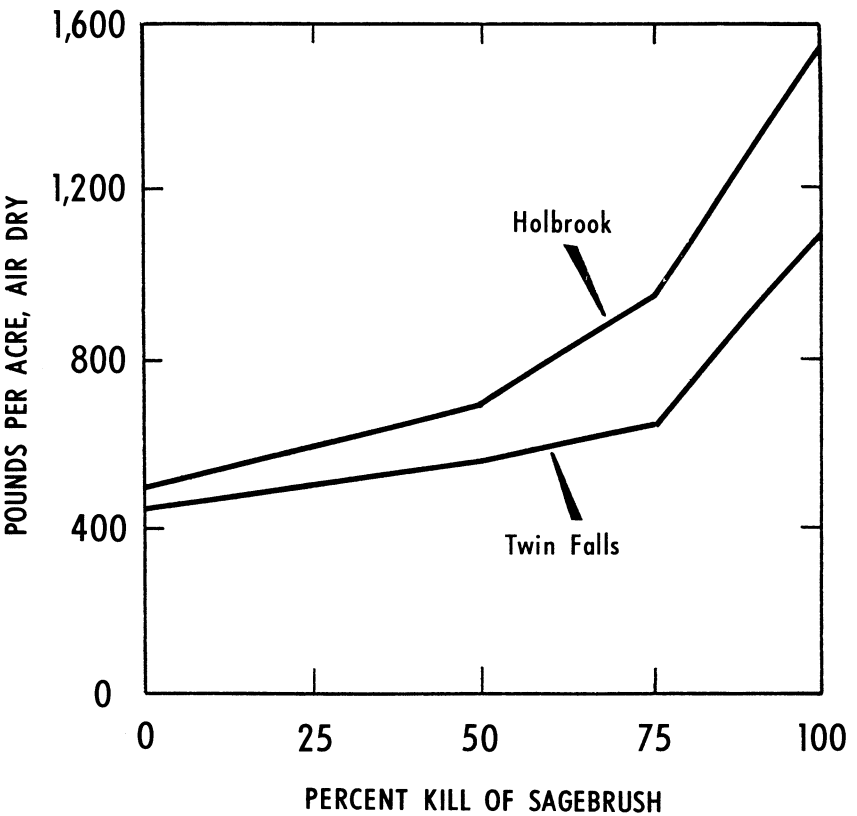

FIGURE 10.—Yields of crested wheatgrass under 4 intensities of sagebrush control at Holbrook and Twin Falls. Average of 4 years (1967–70). Kills were made at 50, 75, and 100 percent of sagebrush.

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FIGURE 11.—Brush thinned 90 percent or to 2 sagebrush plants per 100 sq. ft. at Holbrook in 1968. Though this number of sagebrush plants may be desirable for game birds and animals, the sagebrush competed vigorously with the grass.

moisture in the upper 6 inches of soil under sagebrush and grass and under grass (fig. 13).

Soil moisture was recharged deeper under the grass than under the sagebrush and grass. Based on monthly sampling, soil moisture under the grass at Holbrook was recharged to near field capacity to 48 inches deep in 1969 and 1970, 36 inches deep in 1967, 24 inches deep in 1968, and 12 inches deep in 1966. Soil moisture under the sagebrush was recharged to near field capacity to 36 inches deep in 1969, 12 inches deep in 1967 and 1970, and 6 inches deep in 1966 and 1968.

Twin Falls

The soil at Twin Falls holds approximately 1.9 inches of water per foot of soil at 15 bars tension or approximate wilting and 3.8 inches at one-third bar tension or field capacity. Because of rock, soil samples were taken only to 24 inches. Moisture often penetrated deeper than 24 inches; hence, moisture in the top 24 inches of soil does not show the total amount available to plants. There was little difference between soil moisture under the grass only and under the sagebrush and grass at the 0- to 6-inch depth. At 6 to 12 inches and 12 to 24 inches there was more moisture under the grass than under the sagebrush in summer and fall (table 6). Soil samples were

also taken for a 10-month period in 1969. Soil moisture at 6 to 12 inches was intermediate between 0 to 6 and 12 to 24 inches and is not shown (fig. 14).

Precipitation

Precipitation was undoubtedly a major factor that influenced grass yields. The distribution of precipitation, together with the temperatures during the growing season, were probably more important than the amount of total precipitation (table 1).

Using the water year, October to September, the year of establishment had above-normal precipitation. The second year, 1966,

TABLE 5.—*Inches of water per foot of soil at 5 depths under stands with 20 sagebrush plants per 100 sq. ft. and under grass with no sagebrush on the first of each month at Holbrook. Each figure is the average of 5 years, 1966–70*

Sampling date	Brush treatment[1]	Inches of water per foot of soil for the following sample depths (inches)				
		0–6	6–12	12–24	24–36	36–48
January[2]	S	3.7	3.5	1.6	1.5	1.3
	G	4.2	3.3	2.2	2.4	2.1
February[2]	S	3.7	3.2	2.6	1.8	1.7
	G	4.2	3.5	3.4	3.0	2.5
March[3]	S	3.7	3.4	2.6	1.9	1.5
	G	3.8	3.5	3.5	3.2	2.8
April	S	3.4	3.4	3.5	3.0	1.8
	G	3.6	3.5	3.6	3.4	3.2
May	S	2.8	2.7	3.0	2.8	2.1
	G	2.5	2.7	3.2	3.4	3.0
June	S	1.6	2.0	2.5	2.5	2.2
	G	1.6	2.0	3.1	3.3	2.9
July	S	1.6	1.7	2.0	2.0	1.8
	G	1.7	1.8	2.4	2.7	2.5
August	S	.9	1.4	1.6	1.5	1.4
	G	.9	1.4	2.1	2.6	2.5
September	S	1.3	1.7	1.6	1.5	1.5
	G	1.2	1.7	2.1	2.1	2.1
October	S	.9	1.3	1.5	1.5	1.4
	G	.9	1.4	1.9	2.1	2.2
November	S	1.9	1.3	1.5	1.5	1.4
	G	2.1	1.4	1.9	2.0	2.0
December[2]	S	3.1	2.6	1.6	1.5	1.4
	G	3.2	2.9	1.9	1.9	2.2

[1] S, sagebrush; G, grass.

[2] Sampled only in 1969–70.

[3] Sampled only in 1966, 1969, 1970.

was below normal, and grass yields were the lowest recorded. Precipitation was near normal in 1967 at Holbrook and below normal at Twin Falls. However, the rains were timely; and the soil temperatures were conducive to good growth. Grass yields at both locations were high. At Twin Falls, the most precipitation was recorded in 1970; and grass yields were the highest of any of the years of the study. Precipitation at Holbrook was normal in 1970, but the rains were timely and grass yields were high.

Snow Cover

There was a snow cover every year of the study at Holbrook. The period of snow cover was 2 months in 1966 and 1970, 3 months in 1968, and 4 months in 1967 and 1969. Maximum depth ranged from 11.1 inches in 1966 to 14.5 inches in 1969. There was always more snow in the open than in the brush (table 7). Although there is

TABLE 6.—*Inches of water per foot of soil at three depths under stands with 20 sagebrush plants per 100 sq. ft. and under grass with no sagebrush on the first of each month at Twin Falls. Each figure is the average of 4 years, 1966–69*

Sampling date	Brush treatment[1]	Inches of water per foot of soil for following sample depths (inches)		
		0-6	6-12	12-24
February[2]	S	3.6	2.7	3.4
	G	3.4	2.8	3.3
March[3]	S	4.1	4.2	4.4
	G	4.6	4.4	4.9
April	S	2.4	2.7	2.9
	G	2.5	2.7	2.8
May	S	1.7	2.2	2.4
	G	1.6	2.1	2.4
June	S	1.4	1.6	1.9
	G	1.5	1.9	2.1
July	S	1.3	1.5	1.9
	G	1.2	1.8	2.1
August	S	.6	1.0	1.3
	G	.7	1.2	1.4
September	S	.8	1.4	1.5
	G	.8	1.3	1.6
October	S	1.1	1.3	1.5
	G	1.0	1.4	1.7
November	S	1.3	1.3	1.7
	G	1.4	1.4	1.8

[1] S, sagebrush; G, grass.
[2] Sampled only in 1966, 1969.
[3] Sampled only in 1969.

considerable wind and snow drifting in Curlew Valley where the study is located, the tall sagebrush evidently prevented drifting at the experimental site.

At Twin Falls, a broken snow cover prevailed on January 1 and February 1, 1969, and was not measured.

Rainfall and Snow Interception

Sagebrush plants intercepted both rain and snow (table 7). Following interception, water evaporated from the plant surfaces with

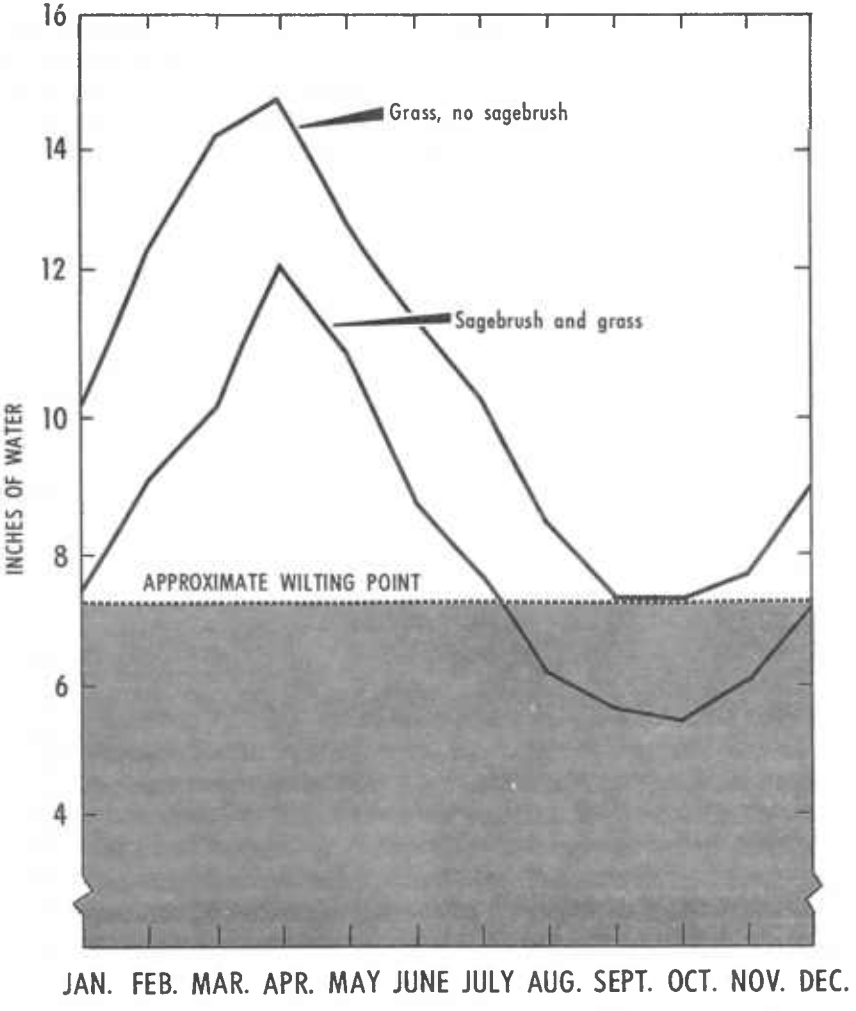

FIGURE 12.—Inches of water in the top 48 inches of soil at Holbrook. Measurements were averaged for the first of each month in 1969 and 1970.

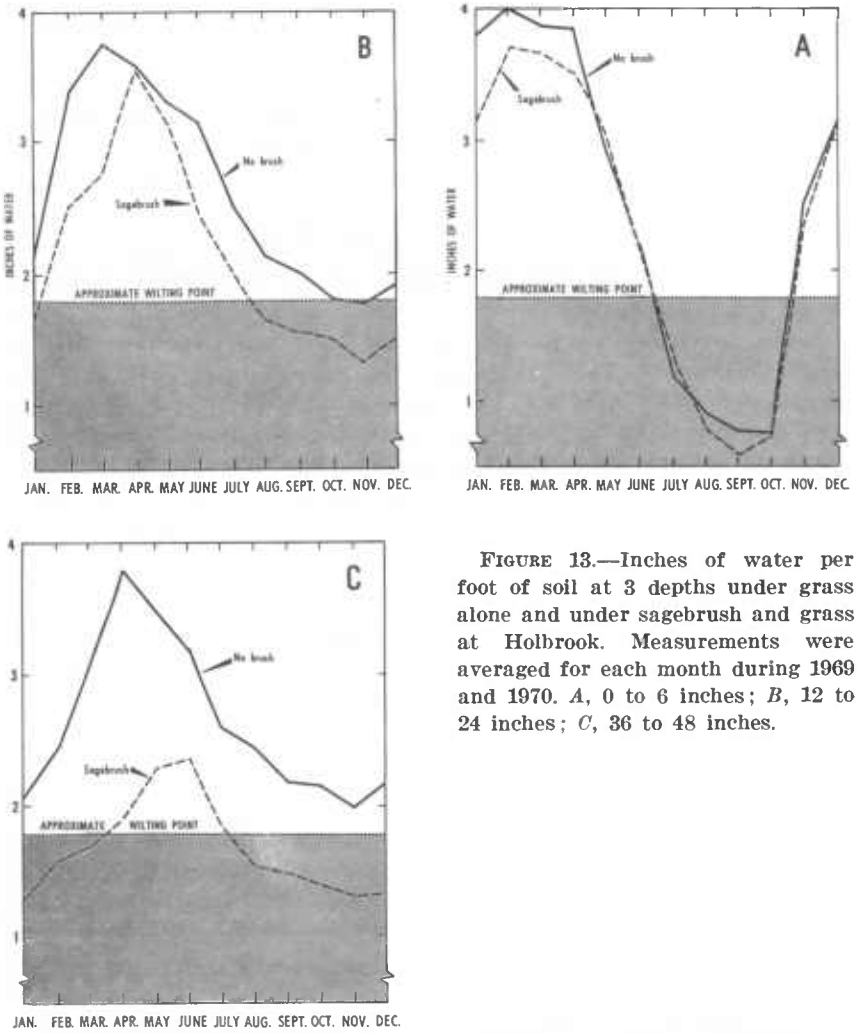

FIGURE 13.—Inches of water per foot of soil at 3 depths under grass alone and under sagebrush and grass at Holbrook. Measurements were averaged for each month during 1969 and 1970. *A*, 0 to 6 inches; *B*, 12 to 24 inches; *C*, 36 to 48 inches.

little water getting into the soil. The lighter the precipitation the greater the percentage which was intercepted. During light storms, hardly any rain was caught in gages under heavy brush. During heavy storms, we saw leaf drip but no stem flow on the sagebrush.

Within each heavy sagebrush plot, 30 percent of the rain gages were under heavy brush, 40 percent under medium brush, and 30 percent in the open. Gages in the open caught over twice the rain caught by gages under heavy brush. However, averaging all gages on the heavy sagebrush plots, heavy brush intercepted 31 percent of the rain at Holbrook and 30 percent at Twin Falls, when compared to gages on the brush-free plots. Sagebrush on the heavy

brush plots at Holbrook intercepted 37 percent of the snow as compared to the brush-free plots (table 7 and fig 15).

The potential rainfall interception and the evaporation from the sagebrush at Holbrook was checked on 10 plants cut at the ground level and sprayed with a rainlike spray. Plants averaged 45 inches high, 30 inches in diameter, and intercepted 1.52 pounds of water. At Holbrook, the number of mature sagebrush plants averaged 7,056 per acre; thus they could intercept 10,750 pounds of water per acre every time the brush was thoroughly wet by rain, which could be be several times during the season.

When sagebrush plants are sprayed with water, evaporation is rapid. On June 29, 1970, with a maximum air temperature of 62° F., plants were hung upright on a fence at 10 a.m. In 1 hour, plants were down to their original weight; in 5 hours, they had the same percent moisture as unsprayed plants; and after 35 days, they ceased to lose weight (fig. 16). Based on these air-dry weights, whole sagebrush plants had 36-percent moisture when cut in the field.

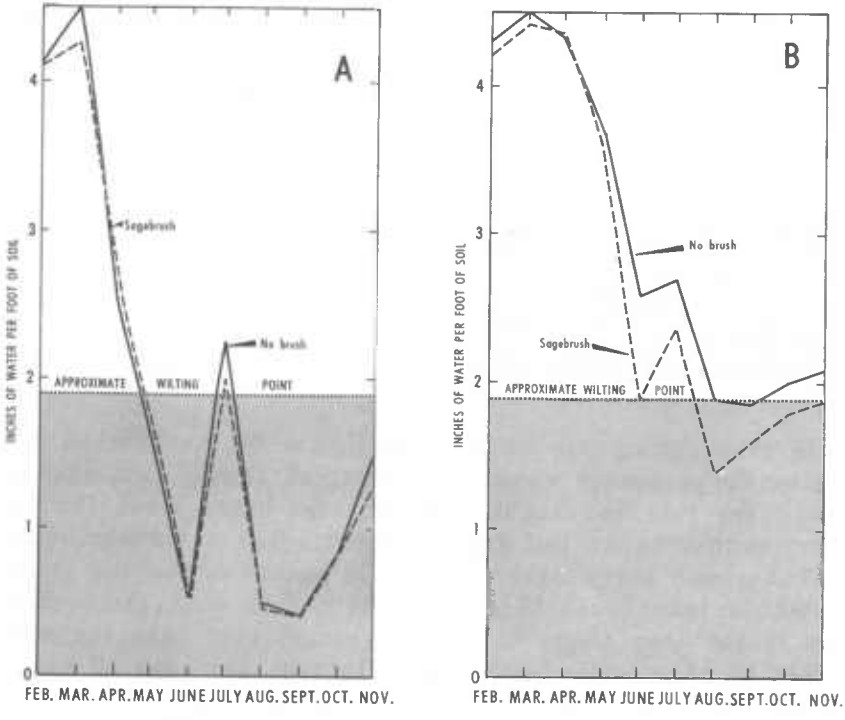

FIGURE 14.—Inches of water per foot of soil under grass alone and under sagebrush and grass at Twin Falls during 1969. *A*, 0 to 6 inches; *B*, 12 to 24 inches.

Roots

Numerous large basalt rocks in the soil at Twin Falls made root sampling inadvisable. At Holbrook, sagebrush plants 40 to 45 inches tall had roots which reached depths of 60 to 72 inches and spread laterally 48 to 60 inches (fig. 17). Crested wheatgrass roots were much finer and did not spread as far as sagebrush roots. Under sagebrush, crested wheatgrass roots had a maximum depth of 42 inches and a maximum spread of 20 inches. Roots from crested wheatgrass plants on brush-free areas reached a depth of 60 inches and a lateral spread of 36 inches (figs. 18 and 19). Visual estimates of grass and sagebrush root distribution in the open trenches were similar to data from sampling.

The concentration of 93 percent of the grass roots and 80 percent of the sagebrush roots in the top 18 inches of soil indicates severe competition between grass and sagebrush. Though both plants have deep roots, sagebrush has more roots at the deeper depths and is thus better equipped to compete for deep moisture.

These samples also indicate that crested wheatgrass has more roots and that roots go deeper and spread more laterally when growing in the open than when growing in competition with sagebrush.

Root yields have been found to be high by many investigators, for example, Schwendiman [5] and Stevenson and White, 1941. Root samples were not adequate to give precise root weights, but they do give an indication of distribution (table 8). At Holbrook, the roots

[5] SCHWENDIMAN, J. L., FOSTER, R. B., and HOGLUND, O. K. THE INFLUENCE OF CLIMATE, SOILS, AND MANAGEMENT UPON THE ROOT DEVELOPMENT OF GRASS SPECIES IN THE WESTERN STATES. Amer. Forage and Grassland Council Proc., pp. 40–57. 1966. (Mimeographed.)

TABLE 7.—*Cumulative precipitation,*[1] *April 1 to October 30, near ground level at Holbrook and Twin Falls and maximum snow depth and water content at Holbrook under 0, 5, 10, and 20 sagebrush plants per 100 square feet*

Sagebrush plants per 100 sq. ft.	Summer precipitation		Snowfall	
	Holbrook	Twin Falls	Depth	Water content
	Inches	*Inches*	*Inches*	*Inches*
0	7.2	4.7	12.6	3.8
5	5.7	3.9	10.2	3.0
10	5.4	3.6	9.2	2.7
20	5.0	3.3	8.0	2.3

[1] Average of 5 years, 1966–70.

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FIGURE 15.—Averaging all 5 years, only 70 percent as much summer rain and 63 percent as much winter snow reached the ground on the brush plots as on the brush-free plots. Photograph shows lack of snow under sagebrush at Holbrook.

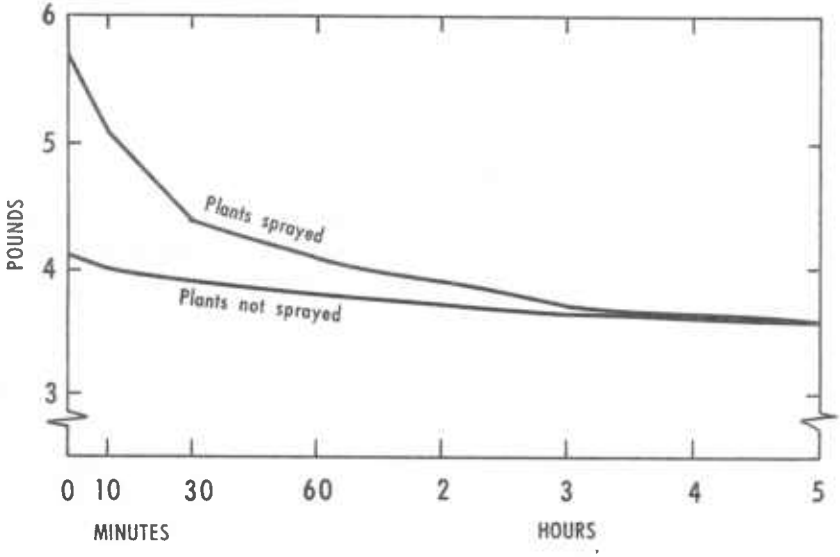

FIGURE 16.—Average weights of sprayed and unsprayed big sagebrush plants for 5 hours following cutting and spraying.

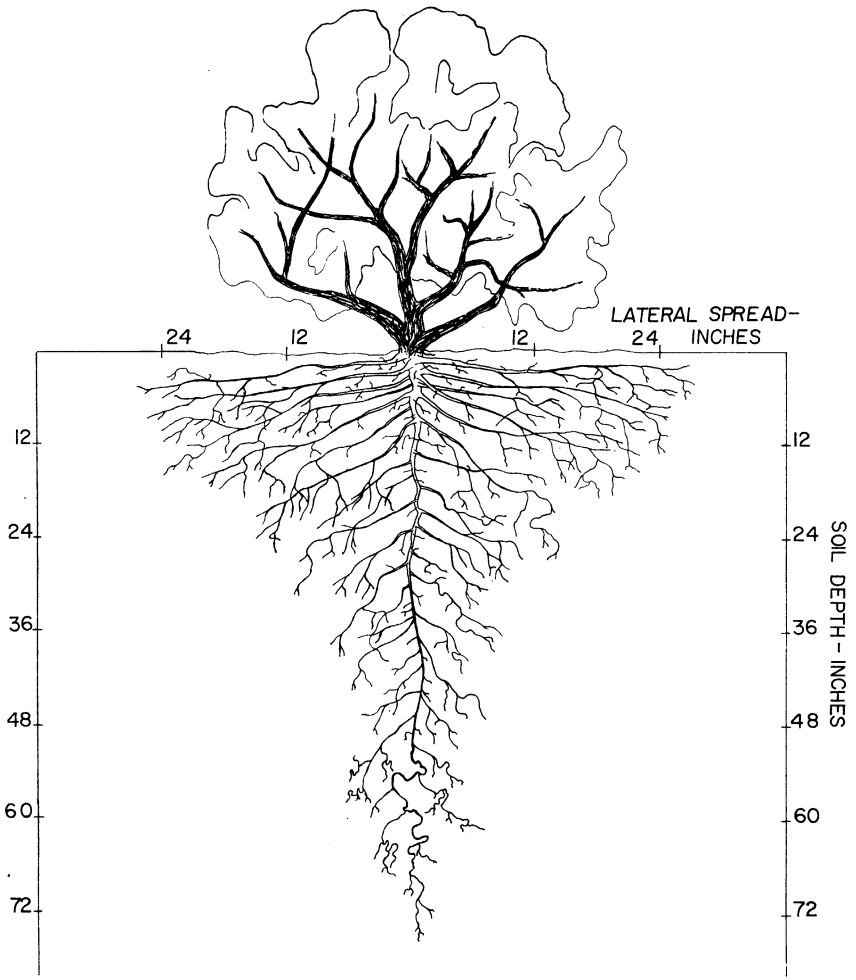

FIGURE 17.—Sketch of sagebrush roots as exposed in the trenches at Holbrook.

of crested wheatgrass weighed eight times as much as the tops. Sagebrush roots weighed 30 times as much as the current top growth of sagebrush and 1⅓ times as much as the total aboveground growth.

Grazing

Grazing was by cattle or by horses. Proper use of approximately 50 percent (35 to 60 percent) of the crested wheatgrass, which was comparable to adjacent range, was obtained in most years. However, in 1966 over 90 percent of the available herbage at Holbrook was grazed by cattle. This severe use appeared to damage grass on areas burned the previous year. However, the burned areas recovered

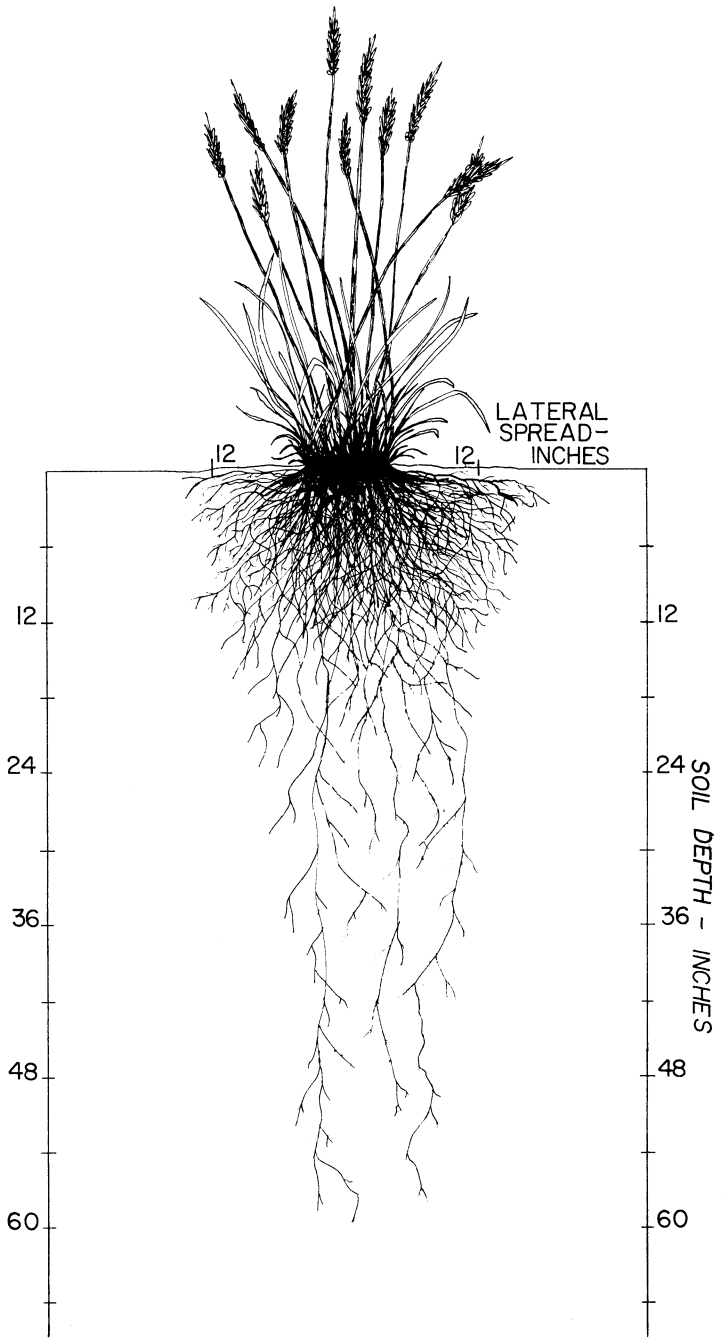

FIGURE 18.—Sketch of crested wheatgrass roots as exposed in the trenches at Holbrook.

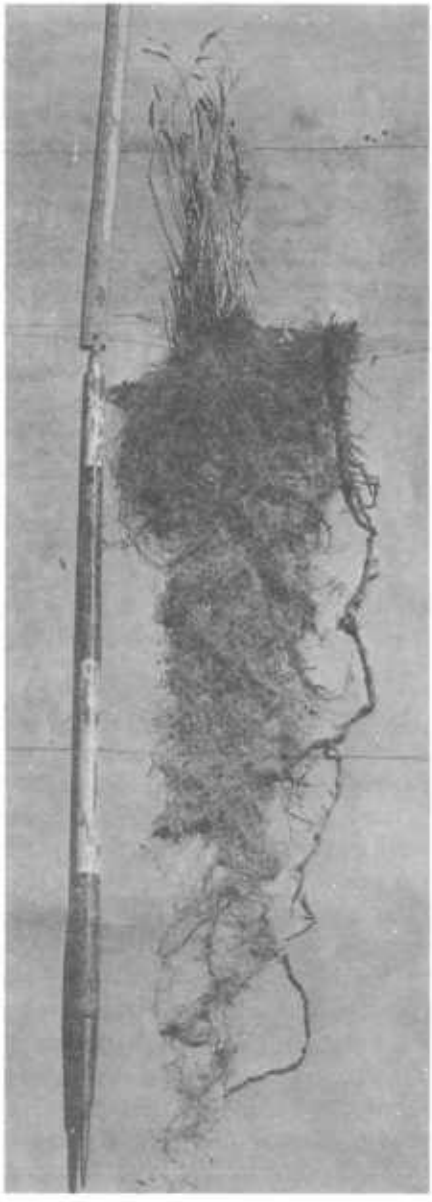

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FIGURE 19.—Roots of crested wheatgrass plant on brush-free area.

TABLE 8.—*Pounds per acre of roots of big sagebrush and crested wheatgrass with the percentage of roots at each 6-inch depth at Holbrook*

Depth (inches)	Big sagebrush [1]	Crested wheatgrass	
		Not under sagebrush [2]	Under sagebrush [3]
	Percent	*Percent*	*Percent*
0–6	53	69	62
6–12	20	15	17
12–18	7	9	12
18–24	7	3	6
24–30	4	1	2
30–36	3	1	1
36–42	3	1	T
42–48	1	1	—
48–54	1	T	—
54–60	1	T	—
60–72	T	—	—

[1] Average of 4 samples; 23,788 pounds per acre.
[2] Average of 2 samples; 15,132 pounds per acre.
[3] Average of 3 samples; 10,955 pounds per acre.

and produced well in 1967. Late summer use by rabbits in 1969 took much of the grass but was not damaging to the stands.

CONCLUSIONS

Grass yields from 1965 to 1970 showed that the greater the reduction of brush, the higher the production of grass. The three methods of brush control did not differ significantly in the amount of grass produced. Two years of moderate grazing use following brush control brought the grass stands to full productivity.

Complete control of sagebrush yielded the greatest amount of grass. During the last 4 years (1967–70) after grass reached full productivity, grass under untreated sagebrush at Holbrook produced 490 pounds per acre. Killing half the brush increased yields by 193 pounds. Killing the remaining 50 percent increased yields an additional 839 pounds. At Twin Falls, the 4-year average of grass under sagebrush was 442 pounds per acre. Killing 50 and 100 percent of the brush gave increases of 115 and 388 pounds per acre, respectively.

If sagebrush is not needed for wildlife or domestic livestock, the goal should be complete kill. The remaining brush suppresses grass most proportionately and is also a seed source for reinvasion. Killing the last 25 percent or five plants per 100 sq. ft. of the sagebrush

gave 135 percent more grass at Holbrook and 98 percent more at Twin Falls than killing the first 75 percent.

In 1970, sagebrush on the untreated brush plots yielded 802 pounds per acre at Holbrook and 304 at Twin Falls. The canopy covered 33.7 percent of the ground at Holbrook and 11.4 percent at Twin Falls. When 75 percent of the sagebrush plants were killed, the remaining plants doubled in yield and canopy cover when compared to plants on the untreated brush plots. This increase in size of the remaining sagebrush plants also shows the need for complete control of sagebrush.

During the growing season, there was more soil moisture under the grass than under the sagebrush and grass. Sagebrush uses more water for growth than grass and because of interception by brush, the soil surface of the sagebrush plots received only 70 percent as much rain, and 63 percent as much snow as the brush-free plots. Thus, an often overlooked and undesirable feature of sagebrush is that it prevents high grass production by preventing rain and snow from replenishing the soil moisture supply. Soil moisture at the deeper depths under sagebrush was seldom recharged by winter and spring precipitation.

Sagebrush reduces root growth of crested wheatgrass. Roots of 42-inch sagebrush plants reached down to 72 inches and spread laterally to 60 inches. Under sagebrush, the crested wheatgrass roots were 42 inches deep and spread 20 inches. Roots of crested wheatgrass on brush-free areas reached 60 inches deep with a lateral spread of 36 inches. Sagebrush roots weighed 23,788 pounds per acre, air dry. Roots of crested wheatgrass weighed 10,955 pounds per acre when growing under big sagebrush and 15,132 pounds per acre on brush-free areas.

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LIST OF PLANTS

Common name	*Scientific name*
Alfalfa	*Medicago sativa* L.
Bluegrass, bulbous	*Poa bulbosa* L.
Bluegrass, Sandberg	*P. secunda* Presl
Cheatgrass	*Bromus tectorum* L.
Milkvetch	*Astragalus cibarius* Sheld.
Needlegrass, Thurber	*Stipa thurberiana* Piper
Rabbitbrush, Douglas	*Chrysothamnus viscidiflorus* (Hook.) Nutt.
Rabbitbrush, rubber	*C. nauseosus* (Pall.) Britton
Sagebrush, big	*Artemisa tridentata* Nutt.
Sagebrush, basin big	*A. tridentata* subsp. *tridentata* Nutt.
Sagebrush, Wyoming big	*A. tridentata* subsp. *Wyomingensis* Beetle
Sagebrush, threetip	*A. tripartita* Rydb.
Squirreltail	*Sitanion hystrix* (Nutt.) J. G. Smith
Wheatgrass, bluebunch	*Agropyron spicatum* (Pursh) Scribn. & Smith ex Link
Wheatgrass, crested	*A. desertorum* (Fisch.) Schult.
Wheatgrass, fairway	*A. cristatum* (L.) Gaertn.
Wheatgrass, streambank	*A. riparium* Scribn. & Smith

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